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ABSTRACT

Hodgson Vocational Technical High School, New Castle County (Delaware), has recently converted from being a shared-time vocational center to being a full-time academic-vocational-technical school. As part of its restructuring, the school instituted a Senior Project, a three-part authentic assessment that combines a research paper, a shop product, and a public, formal, oral presentation. Students select a faculty advisor at the end of their junior year, and the student and advisor work together to orchestrate student progress through the project in a way similar to a dissertation process. The project supports a number of authentic teaching and learning opportunities as it encourages integrated vocational and academic learning. An intellectual component is added to traditional competence- and performance-based vocational assessment. Its most powerful lesson is that work should be meaningful rather than perfunctory. An appendix presents a sample student paper. (Contains 3 references.) (SLD)

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The Senior Project

Authentic Assessment at Hodgson Vocational/Technical High School

Jacqueline Ancess
Linda Darling-Hammond

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A Series on Authentic Assessment and Accountability

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September 1994

A version of this paper will appear as a chapter in ***Authentic Assessment in Action***, by Linda Darling-Hammond, Jacqueline Ancess, and Beverly Falk, to be published by Teachers College Press in 1995.

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Jacqueline Ancess
Linda Darling-Hammond

"When Jake[1] was in first grade for only three days," recalled his mother, "I got an unexpected call from his school to come and take him home because he refused to come out from under a table where he'd been hiding for two hours." She hesitated, as though freshly stung by the pain of an event that occurred eleven years earlier: "You don't know how it feels to have something like that happen to you. What do you do when the school calls and tells you they don't want your child?" Jake was later found to be dyslexic. He is still withdrawn. As a Hodgson Vo-Tech High School senior, however, he shyly explained the geometry he used to construct the blonde mahogany 18th-century pencil-post bed he was exhibiting, and his mother beamed proudly.

Jake was engaged in the formal public presentation of his work, the final component of Hodgson's three-part project program entitled, *Senior Project: An Exhibition of Achievement.* His project committee -- consisting of three teachers: his carpentry teacher, English teacher, and another vocational teacher -- was in the process of evaluating his presentation. They watched and listened intently, barely able to contain their delight. Jake already had completed the two other project components: constructing the product, which was the actual bed (valued at $2,500.00), and preparing a typed, properly annotated, multisource, 20-page research paper on the craft of bedmaking.

In his public presentation, Jake demonstrated his knowledge and skills, integrating the academic and vocational components of his course of study in carpentry and language arts. Guided by note cards, he took his audience through the history and process of bedmaking with carefully planned narration and demonstrations to render the craft he had learned visible and accessible. Jake demonstrated a lamb's-tongue cut -- a cut typically used by 18th-century craftsmen. He passed around a template he designed and a sample of the type of wood with which he constructed the bed. While displaying various tools, he explained their uses and also discussed the factors that influenced his choice of materials: cost, aesthetics, appropriateness, and effect. He instructed his audience in related linguistic phenomena -- such as the derivation of the expression "Sleep Tight" -- as well as in the history of the antique hardware he used.

Jake's committee questioned him to assess the depth of both his academic and vocational knowledge: "What tools did you have that an 18th-century craftsman would not have had?" "How does a crafted bed differ from a mass-produced one?" "What different types of finishes did you use?" "What was the hardest thing about making the bed?" "Why did you choose this project?"

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[1] In general, students' names have been changed and are marked with an asterisk. In this case, by agreement of the student, Jake Lott, and his mother, the name has not been changed. The names of faculty members have not been changed.

Jake's answers to the last two questions revealed the power of the Senior Project to act simultaneously as an assessment of and a catalyst for deep learning. "The hardest thing about the project was the time required to do high quality work. Exact work. Not sloppy work," he said. (Jake's mother later confided that he worked on the bed during spring vacation when school was closed: "He got up at 6 a.m. and went to his co-op furniture shop to work on his bed.")

Jake explained that he chose the bed project for aesthetic reasons and also to challenge himself: "I wanted to see if I could do it. I liked the simple, clean design." His mother revealed how his trepidation turned to new-found self-confidence. "He picked something he didn't think he could do, something he didn't want to do, and found out something he *can* do." Hodgson carpentry teacher Dave Lutz remarked on Jake's initial resistance: "Jake didn't want to do this at all. He almost walked out!" Jake agreed. "I doubt my skills all the time. This proved I could do anything if I put my mind to it. Now I know I *have* skills. I learned that I like making furniture."

The emphasis on authentic performance that characterizes the Senior Project taught Jake a personal work ethic: perseverance, self-motivation, high standards, pride in his craft, and self-confidence. The gathering of family, teachers, and the school principal for Jake's exhibition constituted the ritual for evaluating and celebrating students' skills and knowledge in the school's integrated career and academic program. Already in its second year of operation when we visited during 1991-92, *The Senior Project: An Exhibition of Achievement* had already begun to serve both as a celebration of students' personal achievement and as a symbol of Hodgson's achievement as a community organized for success.

The Paul M. Hodgson Vocational Technical High School is one of three such schools in Delaware's New Castle County vo-tech school district. The Senior Project was the first of many education reform initiatives to be undertaken there in response to the school's recent conversion from a shared-time vocational center to a full-time academic-vocational-technical school. Located in suburbs 20 miles southwest of Wilmington, right off the local highway, Hodgson's nearly 20-year-old building, of modern design, is perched comfortably on a grassy 30-acre campus. Over 800 students from New Castle County -- grades 9 through 12 -- have chosen to attend Hodgson full-time. They participate in one of 22 career programs the school offers in conjunction with a comprehensive academic instructional program. The student body is about 30 percent minority; most students come from working-class families. The students reflect a full range of achievement levels. Approximately 25 percent continue on after graduation to postsecondary schools, roughly 15 percent aim at four-year colleges, and about 15 percent are identified for special education services.

The Rationale for the Senior Project

Under the three-year-old administration of principal Dr. Steven Godowsky, Hodgson launched the Senior Project in conjunction with several other initiatives that focused on

rethinking school goals and practices. Hodgson was eager to incorporate the goals of the Southern Regional Educational Board for higher expectations of vocational students in the areas of communication, mathematics, and science. Hodgson staff became acquainted with Theodore Sizer's ideas about schooling through Delaware's participation in *Re:Learning*, a joint effort between the Coalition of Essential Schools and the Education Commission of the States aimed at restructuring secondary schools to better meet the needs of students. In order to generate interest in reform and to allow staff to examine Sizer's principles, Godowsky sponsored morning and afternoon faculty "conversations" over a period of one year. These conversations became the forum for educational debate among Hodgson staff and the wellspring for the school's restructuring efforts.

Starting with the concept of "diploma by exhibition," and manifesting their commitment to the idea of "student as worker," the staff settled on the idea of assessment by exhibition as the first initiative toward a more ambitious goal of awarding diplomas based on student performance. The use of exhibitions -- activities that enable students to demonstrate expertise -- gave the staff a familiar starting point. Hodgson could draw on its history and expertise as a vocational-technical school with a variety of traditional vocational approaches to competency-based education, exhibitions, and performance-based assessment. The school had long participated in such exhibition-based events as the annual VICA (Vocational and Industrial Clubs of America) competitions; consequently, many students and teachers understood the concept and value of performance-based evaluations of competence. Hodgson students also undertake a number of projects that engage them in real work, producing real products for their own use and for others. For example, Hodgson students recently built dugouts for their baseball field and constructed two portable houses for the county's low-income housing program.

In addition, the English department already required Hodgson seniors to do a research paper integrating the vocational and academic components of their course of study. One outcome of staff conversations was the formation of a faculty committee "to investigate the possibility of expanding the English paper to create a multi-component senior project that would require students to demonstrate skills mastered in career and academic programs" (Godowsky, Scarbrough, and Steinwedel, 1991, p. 1).

The English department's career-based senior research paper, which had recently replaced the traditionally required literature-based research paper, was an ideal starting point for this expansion. It was popular with vocational teachers and successful with all Hodgson's students, most notably with special education students mainstreamed into regular classes. Although the content of the paper had changed from literature to shop, the rigor required by a thorough research process was left uncompromised. Students still had to learn and demonstrate appropriate understanding of research conventions, such as compiling a bibliography, using multiple formats like charts and photographs in addition to text to represent their findings, and gathering their information from a variety of sources; they were also required to type their papers. English chair MaryAn Scarbrough asked the students to also "do some kind of application in the paper. They weren't asked to do a physical project

per se, but many of them did, just because they wanted to find out how [what they had researched] worked, and they wanted to write up their analysis or their results in the paper."

According to Scarbrough, *The Senior Project: An Exhibition of Achievement* was "the next logical step." In 1990, at a summer institute sponsored by the Coalition of Essential Schools, a four-teacher team composed the first draft of the project, a three-part plan including:

- a shop-based research paper requiring students to expand their knowledge
- a shop product, designed and constructed by the student, related to the student's vocational program, and requiring the student to expand his/her abilities
- a public, formal oral presentation

At inservice days prior to the opening of the 1990 school year, the entire staff responded favorably to the plan. A Senior Project Evaluation Committee was formed to make a number of revisions suggested by the staff. The pilot Senior Project implemented that year was built on the school's knowledge base of successful practice, rooted in the school culture itself, and emerged from an internal process of inquiry rather than from an external directive. Thus, the staff had substantial ownership and investment in the project's success.

It was hoped that the conception of the Senior Project as a final exhibition of knowledge -- an accumulation of three years of achievement and skill in one shop area -- would encourage students to demonstrate a level of mastery in both vocational and academic domains. The Senior Project provided the school with the opportunity to reinvigorate and challenge students who were convinced, as Scarbrough said, that they "were at Hodgson because they couldn't make it in the academic world."

The Assessment in Operation

The Senior Project process has five steps, as described in Hodgson's "Senior Project Manual": 1) selecting an advisor and Project Committee members; 2) selecting a topic; 3) researching the topic and preparing the research paper, the product, and the oral presentation; 4) making a formal public presentation before the Project Committee; and 5) evaluation.

Selecting an Advisor and Project Committee Members

At the end of their junior year or beginning of their senior year, students select a faculty advisor from either the academic or vocational-technical faculty. Students and their advisors work together to orchestrate students' progress through the Senior Project in a

fashion similar to the doctoral dissertation process. In consultation with their advisors, students select a Project Committee that serves as a resource during the entire project and evaluates the student's research paper, product, and concluding presentation. The Project Committee must consist of at least three adults, including the advisor, an English teacher, and a teacher from the student's vocational program. Students have the option of adding other individuals to their committee, and some have included representatives from industry and business, ministers, their co-op employers, and former students, as well as other faculty. After students have formed their committees, they must submit the members' names to the Senior Project Evaluation Committee, which plans and coordinates the Senior Project process.

Selecting the Topic

The next step in the process is the selection of a topic. Since one of the project's goals is to increase opportunities for students to challenge themselves, students are encouraged to select topics that are of authentic interest to them -- that pique their curiosity. In order to discover their interests, students must begin to engage in a process of self-inquiry. Through this process, they learn about their talents as well as about their interests, and about the power of their talents and interests to generate initiative, hard work, and satisfaction -- the cornerstones of a life-long work ethic.

Allan Angel, Hodgson dental lab teacher, outlined the process he uses to help students select a topic.

> In their senior year, students pick an area that they're going to specialize in, like dentures, orthodonture, or crown and bridge. From that specialty they have to pick their Senior Project, because they'll be able to use a higher skill level and higher-order thinking skills. The students and I will brainstorm together for a Senior Project topic. It may take two periods, but it's basically what they want to do. If they don't know what they want to do, I will sit with them and review what their talents have been and what they did best in. This helps them make a decision.

Angel's theory about the engagement and sustained efforts of students in their projects certainly appears to prove true. Dental lab projects done by Angel's students on topics ranging from "Glass Teeth" to "Porcelain Crowns" to "Obturators" exhibit both careful lab work and painstakingly clear descriptions of procedures, of advantages and disadvantages of different types of dental materials and options, and of discussions of related physiology, complete with graphics and extensive references. The following excerpt from Angela's* paper on porcelain crowns illustrates how carefully students describe their procedures, defining terms and explaining why each step along the way is important.

> Begin with forming the lingual collar. This is a collar around the tooth on the surface facing the tongue. It runs from contact point to contact point. The contact point is where the teeth touch on each side [a figure follows]. The

> function of the lingual collar is to give strength and stability to the porcelain as it rests on the framework. Enough support should be given to the framework in order to allow the porcelain to be applied without causing problems. It should be designed to support all functioning areas of porcelain. There are a variety of designs for anterior frameworks [a figure follows].
>
> The supporting structures of a wax-up, which is the lingual collar in the construction of an anterior crown, should be smooth to avoid being fractured while being fired. It should have extensions far enough into porcelain to protect the porcelain from damage, as seen in [the figure that follows]. This shows a metal island in the center of a posterior tooth. For porcelain bridges, if the metal is extended to the marginal ridge, this will provide an island of alloy thickness. This will increase bridge rigidity [a figure follows]. A marginal ridge is an elevation of enamel that forms the boundary of a surface of a tooth (Boucher, 346).

By the time Angela reaches the end of her carefully written and illustrated paper, even the totally uninitiated reader knows a great deal about the creation of porcelain crowns. She concludes her paper with this statement.

> As you can see, there is a great deal of time and artistic skill put into the fabrication of a porcelain crown; however, it is well worth it for a nice smile. By doing this research paper, I have learned many new things that will benefit me in my dental career. Hopefully, I have successfully explained to you the step-by-step procedures in fabricating a porcelain crown. Perhaps you have a porcelain crown, or maybe someday you will. Now you have an idea of how one is made.

The reader is apt to heartily agree. Other students' research papers, like Angela's, also relate their own career intentions to the topic they examine. For example, in "Diabetes and the Medical Secretary," Melodie* begins her paper this way:

> If you were a diabetic, would you want yourself in the hands of a health care professional who knows nothing about your disease? It is very important for a medical secretary to inform her employer of new technologies on the market, to let the doctor know if the diabetic patient is experiencing problems coping with the disease, to offer any services she can, and to help the patient further understand this disease, and to be a friend who listens and cares.

Melodie's paper goes on to review types of diabetes, risk factors, symptoms, complications, effects, and treatment. Then she outlines the responsibilities of a medical secretary in ensuring proper communication with the patient, providing instruction, and managing emergency situations. In reading this and other student projects that tie the student's career interests with an area of in-depth inquiry, a reader feels as though he or she

would be fortunate to be helped by these young people with the services they are being trained to provide.

Because the project topics emerge from the interests, talents, and strengths of the students, and because they elicit their curiosity, they have the potential to be intrinsically motivating and to deflect students' initial and lingering resistance to the hard work that the projects demand. Both Lutz and Carolyn Steinwedel, special education English teacher, delight in telling stories of students who, when they learned about the project requirements, threatened to transfer to other schools, or said they thought the staff had gone crazy to think that they and their classmates would actually take the difficult project seriously enough to do it and complete it. Joshua*, a Hodgson senior, recalls that "Everybody, like, had a problem with the Senior Project at first, because nobody wants to do the work. Because you're seniors, you want to lay back and just cruise through."

The students at Hodgson select their topic in consultation with their Project Committee, and both the shop teacher and the English teacher, along with the advisor (if neither of the former two acts as advisor), must formally approve the selection. If any of the teachers is dissatisfied with the choice, they confer with one another and with the student until a consensus is reached. The English teacher then submits the approved topic to the Senior Project Evaluation Committee, which formalizes the agreement by publishing the student's name, topic, advisor, and committee. The student's commitment then becomes public knowledge.

Although the procedure for topic selection is streamlined and smooth, the process of decision making about the topic is more complex and captures the untidiness of pathfinding inherent to the project as a whole. Lutz explains that evaluation criteria drive substance, focus the staff on the rigor of project topics, and direct the staff's discourse about the project back to its goals. Criteria such as the demonstration of higher-order thinking skills, originality, and creativity set a framework for the committee's discussion about the suitability of individual students' selections. While a student's interest and curiosity about a topic can ignite and sustain self-motivation and perseverance during periods of frustration, these factors are not enough in themselves to assure choices of substance and appropriate challenge -- topics that will, as required by the Senior Project guidelines, extend students' knowledge.

During the first year of the project, mundane topics were not unusual. Lutz described them as "topics that were in-shop practices and had very little to do with higher-order thinking, and challenging and pushing the student." Lutz cited "The Alphabet Line" as an example of a first-year topic that was basic to a drafting course, and compared it to a second-year topic from the same shop, "Cochran's Grange: A Study." "The Alphabet Line" required the student merely to demonstrate knowledge of definitions of various lines, while the "Cochran's Grange" project demanded that the student study an historically significant architectural structure from an interdisciplinary perspective.

To extend the scope of projects during the second year, the Evaluation Committee

encouraged increased collaboration between the English and shop teachers and involved the librarian as well. Projects completed during the second and third years of the program reveal more challenging topics that reflect a sophisticated notion: not simply integrating English and shop subjects, but employing multiple disciplines. Projects entitled "Satellite Communications" and "Brain Tumors," for example, rely on extensive library research from scientific and medical journals, as well as on interviews and other sources of information. Many projects now also include historical research. For example, this excerpt from a Senior Project on obturators ("a dental prosthesis designed to close a hole in the palate") begins by noting:

> The first obturators were constructed in the early 1500s by Ambroise Pare. He was from France. These were made with a large piece of gold to cover the defect. On top of this gold was a small clip. A sponge was put into this clip. The sponge was put in the nasal cavity to absorb fluid. Obturators were first brought to public attention in 1563 in Pare's ***Ten Books of Surgery***.
>
> Pierre Fuchard also made some of the early obturators. This is a picture of an obturator made by Fuchard. This type of obturator was not practical or comfortable but it was used for many years. [Figure follows here.]

The paper goes on to describe, in exceedingly thorough detail, how these devices are currently made, defining terms and reasons for particular procedures and discussing aspects of mouth physiology that are important for those designing and fitting the devices. Once again, the reader finishes this comprehensive and carefully explicated account with the sense that if one ever needed an obturator, this is the person one would want to have preparing it.

The range of student interests and talents as shown in their choice of topics is quite wide. Other projects have included: "History of War Propaganda Poster Design," "AIDS and the Dental Office," "Drainage Systems," "Malpractice Insurance," "Fiber Optics," "Using Information Systems and Service Skills in Sports Journalism," "The Effects of Stress on Children," "Cajun-Style Cooking," "Nail Disorders," and "The Architecture of the Sistine Chapel and its Effect on Other Churches."

Scarbrough commented on the significance of ongoing communication, negotiation, and shared decision making between academic and vocational faculty to ensure that students select self-challenging topics:

> I say to the shop teachers, "Nobody knows this kid better than you. You have them three periods a day and you've known some of them for over three years. You know what this kid can do better than I know what this kid can do. When you have to sign that paper [approval of the topic], when he has picked a topic, don't sign that paper unless you're sure that the topic is something challenging to that student." Shop teachers reject topics left and right based on that.

I have a kid right now who wants to do screw threads in machine shop. He and I and the shop teacher sat down and I said, "Okay, now you tell him -- the shop teacher -- what you're going to do for your product in shop. What are you going to make?" Because we had talked about what he was going to research. And he said, "This is what I want to do." And the shop teacher said, "Too easy." And the kid said, "Well, okay, *this* is what I'll do." And the shop teacher said, "Nope. Too easy." So the kid said, "What would you like me to do?" The shop teacher said, "This is what I'd like you to do." And the kid said, "Well, that's hard." And both the shop teacher and I said, "Yes. But it's doable, isn't it?" The kid said, "Yeah. I could do it if I really put my mind to it." That's what we want.

Sometimes, the shop teacher will approve a topic that sounds fine to me, but the librarian will say, "We can't get those materials," or "It's not narrow enough." Then the shop teacher and the librarian have to come to an accord.

In order to increase the active participation and support of the staff for the Senior Project, Hodgson provides regular opportunities at inservice meetings to elicit teacher feedback. This input is promptly followed up on. When shop teachers wanted to be regularly rather than intermittently informed about their students' progress, the English teachers, who were keeping the forms and records of students' progress, quickly put together folders with checklists attached to the inside flaps. Such responsiveness builds credibility among the staff and increases the level of ownership teachers feel for the Senior Project.

Preparing the Research Paper, the Product, and the Oral Presentation

Once students' topics are selected, they begin both their research and their work on the product. Malik*, one of Hodgson's star athletes, explains how the countervailing forces of resistance and authentic curiosity coupled with relentless teacher encouragement propelled his project -- a 3/4" to scale, basic residential house -- toward completion.

When I first started, I was like, "Man, forget this! I don't want to do it." And my teacher, Mr. Sarro, he's like, "What are you talking about? You're going to get this thing done." So I said, "All right. I'm going to do it." At first, it seemed like it was too hard, like it was going to be a whole lot of work, and I had a whole lot of things going on. I was training sports around the clock, and I didn't think I had time to do a project that big. But I just made time, stayed after school. I used to come in after games and come in at night -- they had night school -- and work on it, because *I wanted to see it get done. I wanted to see what it looked like. I mean, after you draw up all the plans and you looked at it, I said, "I wonder what it's going to look like when it's sitting right in front of me."* [Italics added.]

As students get under way, they are spurred on by their teachers as well as their innate

drive and curiosity. Both their English and shop teachers give them class time to do the work on their papers and products, and to practice for their public presentations. Faculty members systematically teach students the skills necessary to successfully engage the tasks. For example, English teachers provide a step-by-step process for conducting research and for writing research papers. They show students how to design and use visuals in their public presentations, as well as how to use note cards as cues.

The student paper shown in the Appendix is representative of many others in its use of graphics, its logical structure, clear exposition, and substantial bibliography. Most papers written during the second and third years of the project (1992 and 1993) contain all of the structural features of a carefully constructed research paper: outline and table of contents; introduction, topically-organized body, and conclusion; charts and figures to illustrate key points; definitions of key terms; and appropriate citations to literature and personal interviews. The consistency with which the student papers include these elements of expository writing makes it clear that the students are not left on their own to magically uncover the secrets of writing a research paper. They are carefully taught.

Shop teachers guide the design and construction of the product, directing students to useful books, suggesting materials, participating in students' decisions, and helping them to solve problems as they arise. Among the products constructed in 1992, in addition to Jake's bed and Malik's house, were an irrigation system for Malik's house, a full set of dentures, a course and kit for "dressing for success," a catered school dinner, and a cut-stone fireplace.

Students schedule regular meetings with their advisors and committees just as doctoral students would when working on their dissertations. Committee members act as mentors and coaches, guiding them to resources, encouraging them during setbacks, and correcting the many drafts of their research papers, which must be submitted periodically for review during the composition phase. During these reviews, the shop teacher critiques the content while the English teacher evaluates usage and style, and both make suggestions for substantive revisions. Students are responsible for keeping a log of these meetings and must adhere to deadlines set by the Evaluation Committee as well as by their individual teachers.

Because the Senior Project is designed to encourage students to extend their knowledge, students' research must take them beyond the confines of the school library and texts. Hodgson's library is linked by computer to public libraries around the state, which gives the librarian access to a wide variety of publications needed for student research. Students' research as a whole, in fact, often takes them beyond the confines of the school. They conduct research the way social science researchers do, and the authenticity and nonroutine quality of the process impress and excite them. Frank*, a special education student, explained how he researched his project on domestic water well systems.

> When I first started, Ms. Steinwedel told me to call around, to ask for information on the phone. I thought, "I'm not gonna get an answer. Nobody's gonna help me." But I got on the phone and started calling people in the

phone book. And they're like, "Come on over. We got all kinds of information on well systems. You can take pictures. Bring your camera." I had all kinds of information for my paper. Got all kinds of packets and rock samples. I wrote to Gould's Pump -- it's like the biggest well pump company around -- and told them what I was doing a Senior Project on. I told them anything that they could donate to me for my project would be a good help for me. And they sent me information. They sent me switches, electronic switches, you know, when the water cuts off.

I went to the University of Delaware -- to the center where they study the earth by digging wells. They dig down and test the different levels of the rock, different types of rock, granite and other kinds. They study the earth, test the water, and drill wells. I have a picture of the drill. They had a drilling truck there -- had everything. *They had different definitions for a well, like three definitions for a well, instead of the one definition in the dictionary.* I went to the University and spoke to the professors in the department. They just get paid to study and write little pamphlets all about wells, ground water, statistics on wells in Delaware. Everything, everything you'd want to know about wells, they had it there. They knew about it. I just sat down and had a meeting with them. I came in, signed in on a little paper, was talking to them for about an hour. They let me leave school! I had permission to go there! Came back to school. Took pictures down there and everything. Even let me operate the drill truck. I was in there driving it! [Italics added.]

The impact of Frank's experience is best captured by his awareness of Hodgson's departure from school conventions, such as permitting him to leave the school and trusting him to negotiate his own learning, especially considering that he is a special education student. Predictably, Frank's self-initiated field experience expanded his knowledge of wells, but this new-found independence also released him to critically evaluate sources of information (i.e., his discovery of the dictionary's limits). He became a more knowledgeable and critical researcher.

Other students have used their co-op employers in the development of their project. Employers have provided technical support as well as information. Some students have integrated their co-op work experiences into their project. They have had themselves videotaped working at their job and then included the tape in the project.

The Formal, Public Presentation Before the Project Committee

The culmination of the Senior Project is the formal public presentation, during which students synthesize the learnings of their research and product. The presentation cannot be less than ten minutes or more than thirty. This is the most intimidating component of the project for the students. Erica* explained:

> People were worried about talking in front of people, like getting in front of the committee, as we have three or four people that you have to get up in front of and talk to. People didn't want to do that because they figured they'd all start laughing, or choke up and start stuttering. They have to do it to get over it.

Malik's presentation lasted for one hour. He presented his project for half an hour and was questioned in the remaining half hour. As at Jake's presentation, the questions asked were both technical and general. When the visiting state superintendent asked Malik how he determined the pitch of the roof on his model residential house, Malik explained, step-by-step, how he used the Pythagorean theorem. He continued to explain how all of his school subjects related to his project. His initial fears gave way to exhaustion; each time he thought he was finished, someone else would ask a question. "But," he said, "I learned how to speak in front of people. I had never done that."

Dave Lutz commented, "We're looking to see if kids can think on their feet. We're looking for higher-order thinking: Is this something they're repeating from a book they read, or do they really know it? Can they think? Can they synthesize this information? Can they apply it to another situation?" The students' and teachers' responses to the public presentation reveal how it takes the research paper one step further: It tests the depth and degree of students' personal integration of knowledge and it calls for *their* voice -- the unique way in which they have constructed this knowledge, how they have made it their own, and how in a public forum, in response to spontaneous questions, they reconstruct it and enrich it as their own. A comparison between students' preparation for, on the one hand, a public presentation, and, on the other, traditional testing, illuminates a fundamental difference in the potential for lasting learning. In preparation for the public presentation, students review for deepened understanding, as opposed to conventional testing, where they memorize for short-term recall.

The public presentation component of the Senior Project turns out to be both the most powerful as well as the most threatening learning task for many students. It is the only component that a few students have refused to do, and that some parents have objected to as being too difficult. Scarbrough recalls students telling her, "I'll do that paper. I'll do that product. But I'm not doing the oral presentation!"

But the old saw about the greatest risk bringing the greatest reward holds true. The public presentation teaches students about learning and knowing in the most profound way. They learn that "knowing" means "internalizing and owning knowledge." And they learn that "ownership" can occur only through the individual struggle of having to make personal sense and meaning of information and experience. The public presentation is the kind of incentive necessary to induce the struggle required for the construction of authentic knowledge because it is an act of public accountability. Students come face-to-face with their judges and their actual work instead of participating in a proxy test of their ability to recall a test designer's definition of knowledge. They define their own knowledge by making the decisions as to

what to present and how to present it.

The oral presentation, while providing students with the opportunity to construct and express knowledge in their own voice, also demands that they locate that voice. This is both a liberating and a terrifying responsibility. Anthony explained, "I think people are scared about talking in front of a lot of people, because they really don't know anything about the subject when they start. But once they get all this input into their brains, it comes out once they start talking about it. It makes it a lot easier on you after you do all your research." Erica, in the same vein, reported, "At first I was embarrassed to get up in front of a whole lot of people. But I'm not nervous anymore because I think I know what I'm talking about." The presentation persuades students, as well as their assessors, that the student truly understands.

Evaluation

Although the Senior Project creates the opportunity for authentic interdisciplinary learning, evaluation for the project was still departmentalized when we were conducting our research, reflecting the school's struggle toward vocational and academic integration. Each of the three components -- research paper, product, and public presentation -- constitutes a grade for either shop or English. Although the English teachers have agreed to a uniform departmental credit policy, each of the shop teachers retains individual credit policies. The Senior Project research paper fulfills the English requirement for a research paper, and the formal public presentation constitutes the English final examination. If students choose not to do the Senior Project, there is a strong likelihood that they will not pass the English course. The Senior Project product is integrated into the shop course final examination, which constitutes 10 percent of students' vocational grades. Some shop teachers, however, assign the full 10 percent credit to the Senior Project product, while others assign less.

This variation in credit policies reflects the continuing resistance to collective decision making. According to Steinwedel, this resistance can be affected by tackling the issue of ownership of the project. As ownership increases among the faculty, so will their capacity for the consensus necessary to formulate a consistent credit and grading policy. Lutz's analysis reveals some of the dilemmas, instructional in themselves, that a school confronts when it undertakes assessment reform. According to Lutz, old habits don't die easily, responsible curriculum reorganization is complex, and a balance between consistency on the one hand and respect for individual course integrity on the other is not quickly struck.

> Some shop teachers have other things that are legitimate that they need to incorporate into the final exam. For example, in cosmetology: To become a cosmetologist, students must pass the State Boards, so the cosmetology teacher wants the students to demonstrate a readiness to pass the State Boards. Some shop teachers have used written exams for ten and twenty years and they don't want to give them up. They're uncomfortable with performance assessment as opposed to a written assessment. You work toward consistency, yet you also

have to work toward the individualization of each shop, which is trying to prepare students for specific vocations.

The potential for collaboration between the academic and vocational faculties is evident in the evaluation system and grading rubric for the public presentation. Members of both faculties created this assessment, which integrates judgment criteria used in both domains. As used during the 1991-92 school year (though since revised somewhat), the grid for evaluating the public presentation relies on four performance indicators (see Figure 1): content (30 points), organization and plan of work (30 points), communication skills (30 points), and personal appearance (10 points). Each member of the Project Committee scores the presentations on the grid, which totals 100 points.

The criteria for evaluating content require students to exhibit understanding, knowledge, creativity, originality, higher-order thinking skills, proper procedures for demonstrations, and appropriate responses to questions. For the organization and plan of work, students must demonstrate the use and understanding of conventions, show evidence of preparation, use appropriate aids and equipment, and finish within time limits. In their exhibition of communication skills, students must communicate clearly, using proper grammar, and maintain good posture and eye contact. Their personal appearance must exhibit dress that is appropriate to their project. In each category, numerical ratings correspond to judgments of excellent, good, satisfactory, and unacceptable.

Immediately after the presentation, the committee members individually complete their grids and briefly meet to total their scores for a single combined score. The committee then conveys the score to the student. If serious discrepancies occur among committee members, the committee will discuss them. Simultaneously, students complete a Student Survey regarding their own experience of and views about the Senior Project, which the staff then uses to review, evaluate, and continually revise the project itself and the way in which it operates. A staff committee meets one afternoon a week to discuss and develop project changes.

In the first year of the Senior Project, although none of the 85 students who took part in it failed to complete it altogether, three students refused to do the public presentation component (all of these had sufficiently high grades that they did not need to do so in order to pass), and a few students did not complete the research paper component, although they did prepare and present a product. In the second year, with increased preparation and support for the program at Hodgson, along with the strengthened expectations of full participation born of experience and prior success, staff members felt confident that an even greater number of students would attempt and complete a full project. In fact, in 1992, 144 of the 150 students enrolled in senior English successfully completed the Senior Project.

Although the Senior Project is quite sophisticated instructionally, as the conflicts surrounding grading and credits reveal, its full impact on instruction that integrates academic and vocational learning will be known only when more of the tensions articulated by

Name: Senior Project: An Exhibition of Achievement Date:

Shop: Public Presentation Evaluation Form Advisor:

Topic:

Evaluation Components	Excellent	Good	Satisfactory	Unacceptable
CONTENT Total pts. 30	28-30	25-27	20-23	0-19
•Demonstrates thorough understanding of knowledge •Demonstrates creativity and Originality •Exhibits a higher order of thinking •Uses proper procedures for demonstrations •Responds appropriately to questions				
ORGANIZATION AND PLAN OF WORK Total pts. 30	28-30	25-27	20-23	0-19
•Follows guidelines •Uses introduction and closing •Shows evidence of preparation •Uses appropriate aids, equipment, etc. •Stays within time limits				
COMMUNICATION SKILLS Total pts. 30	28-30	25-27	20-23	0-19
•Communicates clearly •Uses proper posture, eye contact, etc. •Uses proper grammar				
PERSONAL APPEARANCE Total pts. 10	9-10	8	7	0-6
•Wears appropriate dress, uniform or costume				
Total Points				

12/17/90

Figure 1

Steinwedel and Lutz are resolved. This resolution process is aided by the sensitive and steadfast leadership of Godowsky, who respects and manages the tensions created by his vision for reform and by the varied responses of the staff to change. Godowsky's leadership combined with the energetic commitment of a core of academic and vocational teachers has been critical in enabling the Hodgson staff to tolerate the contradictions, conflicts, and ambiguities inherent in any change initiative. As the Senior Project increasingly penetrates the culture of the school with new rituals each year, Godowsky and the Steering Committee have become increasingly confident about setting a deadline for converting the school's evaluation practices from a system of graduation-by-credit to a system of graduation-by-exhibition that fully integrates the academic and vocational programs.

Influences of the Senior Project on Teaching and Learning

As the Senior Project has begun to take hold at Hodgson, faculty and students note differences in the nature of teaching and learning opportunities that occur. These result from a number of factors: the focused energy students apply to their in-depth inquiry and the ownership and pride they develop in their work; the collaboration and increasingly shared norms among teachers in discussing and shaping teaching and learning; and the opportunities for interdisciplinary study that allow students and teachers to look at ideas and problems in new ways.

The Kinds of Learning Reflected in Students' Projects

One of the things that stands out in reviewing students' Senior Projects is how consistently students take integrative approaches to their topics, looking at them through several disciplinary lenses and from a number of vantage points. For example, Tricia's* paper on "Medical Malpractice" includes actual case studies of malpractice cases, while also covering legal considerations of relevance to a medical assistant (breach of duty, contributory negligence, comparative negligence, and assumption of risk, among others). Using mathematical tools in a series of graphs and charts to illustrate the dramatic annual increases in malpractice claims and insurance premiums, she then turns to a scientific and medical explanation of one area of frequent malpractice complaints -- laparoscopic surgery.

Another common characteristic of the papers is how consistently they weigh and balance the pros and cons of different technologies or approaches to a problem. Paul's* paper on "Roofing in America" traces the history of roofing materials, recounting reasons for the use (and disappearance) of thatch in the British Isles and in America through the mid-17th century, of ceramic tile through the mid-19th century, and of slate, metal roofing, asphalt, tar, and wood shingles. He also offers a careful analysis of advantages and disadvantages for each type of roofing.

> Records show that slate roofing was used before the American Revolution. During the Revolutionary period, only elegant homes, such as the Carpenter

House in Philadelphia and the Thomas Hancock House in Boston, were covered with slate. After the Revolutionary War, slate usage became more common. In fact, by 1830 it was reported that nearly "half of the roofs in New York City were covered with slate." Slate was one of the popular roof coverings of the time (Waite, 138).

Slate was a valued roofing material. It was favored for a number of reasons. One was that slate was a maintenance-free roofing material, unlike other roof coverings such as metal. Slate was also regard (sic) because of its "handsome appearance" (Waite, 138-39).

Like other roofing materials, slate did have its drawbacks. One was the cost. Also, slate was a heavy material that put excess stress on the roofing system. For a time, there was a decline in slate until the population explosion during the middle of the ninteenth (sic) century (Waite, 139-40).

Diandra's* paper, entitled "Glass Teeth," describes the advantages and disadvantages of cerestore, ceramo-metal, and dicor crowns in terms of cost, aesthetics, strength, and X-rayability, and goes on to define how they are made and used. Greg's* paper on "Trusses" compares the different kinds of trusses and the relative advantages of using trusses versus rafters in the construction of houses and other structures.

While these three papers, which were completed in the first year of the Senior Project (1991), exhibit evidence of analytic thinking, they are not nearly as sophisticated as the papers and projects completed by the graduating class of 1993. These later papers exhibit more analytic depth in their treatment of concepts and ideas; they are also more clearly written, with more complete and informative discussions and bibliographies.

In these later projects, more sophisticated treatment of science topics and more extensive use of mathematics are also evident. Laura's* paper on the "Diagnosis, Treatment, and Nursing Care of Patients with Frontal Brain Tumors" explains at length the structures and functions of the brain, the types of brain tumors, the causes, incidence, symptoms, and treatment of tumors, as well as nursing care for a patient following surgery. An array of standard medical texts on oncology, along with basic and specialized nursing texts (e.g., ***A Guide to Neurological and Neurosurgical Nursing***), are referenced throughout. She also cites an interview she conducted with an expert. The clarity of the discussion of the brain and of tumors is impressive. The paper exhibits an understanding of the material that extends beyond rote regurgitation of what the student read. For example, concluding her clear description of the parts of the brain, Laura observes:

The right hemisphere of the brain controls the left side of the body and the left hemisphere of the brain controls the right side of the body. This is because nerve fibers from the spinal cord cross from left to right and right to left. This takes place in the medulla oblongata (Austrin and Austrin, 358).

Having explained the structures and functions of the brain, I now proceed to the discussion of brain tumors in adults. A brain tumor is an abnormal growth of cells within the skull. When the growth of cells progresses, it creates a problem(s) because the growth presses on the normal brain tissue, interfering with the specific functions the brain controls (Miller and Keane, 160).

Tumors can be benign or malignant. A benign tumor is non-cancerous and a malignant tumor is cancerous. A doctor is able to determine whether a tumor is benign or malignant from looking at x-rays. The benign tumor is usually oblique and has a smooth surface. A malignant tumor has projections and is somewhat star shaped (Weigand). . . . Malignant tumors grow and metastasize. "Metastasize" means the tumor can spread through the circulatory system to any part of the body (brain). For example, tumors can metastasize from the lungs, breasts, ovaries, kidneys, and GI tract. Most brain tumors metastasize from the lungs. Brain tumors can originate in the brain, but once they develop there, the tumors usually don't metastasize (Leslie, 82).

Laura continues with a thorough discussion of causes, symptoms, and treatments of different types of brain tumors, before concluding with a section on nursing care. This excerpt illustrates that she has a creditable grasp of the goals of nursing care, especially for a young high school student who has not yet even entered nursing education.

Following surgery, the patient must maintain reduced intracranial pressure (ICP). To reduce intracranial pressure, the head must always be in an upright position. Neurological checks are another way to take precautions. Neuro checks are check-ups done by the nurse or doctor to be sure the patient is still stable. Neuro checks are done every hour. Vital signs are checked, medication is given, and the nurse checks to see if there are any signs of ICP. Some signs are headache, disorientation, dilated pupils, and restlessness. The most important assessment is to make sure there is no pressure on the brain (Weigand; Leslie, 85).

Positioning the patient is very important after surgery. Do not lay the patient on his operative side because it puts pressure right on the brain and could displace brain structures (Weigand; Leslie, 85). Know whether the patient has had supratentorial or infratentorial surgery. That lets the nurse know what position to put him in. Elevate the patient's head 30 degrees if he's had supratentorial surgery. Elevation of the head is very important to increase the flow of blood to the heart from the peripheral vessels. Peripheral vessels are vessles (sic) in the limbs. If the patient had infratentorial surgery, he may have to stay off his back for 48 hours (Long and Phills, 507). [Here follows a discussion of infratentorial and supratentorial surgery.] If there are changes in the patient's vital signs, intracranial pressure, or level of consciousness, report them immediately to the doctor.

Mike's* paper on "Satellite Communications Systems," in the Appendix, demonstrates, like Laura's, a clear understanding of the functioning of the satellite systems he set out to examine. He includes an overview of the history of satellite communications; a discussion of satellite positioning in space, drawing on earth science and physics principles; and a technical description of how satellite systems operate. These are supplemented by carefully chosen graphics to explain and illustrate key concepts. This excerpt demonstrates how clearly Mike is able to explicate what he has learned. Following a definition of elliptical and circular orbits, supplemented by graphic illustrations, Mike explains:

> Due to the fact that a satellite must be in direct sight in order to send or receive to or from a given point on earth, it is important to know the amount of time a satellite is in view. The longer the satellite is in view, the more data that is able to be sent and received. A satellite in an elliptical orbit will be in sight for varying amounts of time during its orbit. This makes it hard to predict and follow. Satellites in circular orbits, however, are visible for the same amount of time every time they appear. Because they are predictable, they are much easier to follow. This made circular orbits the best choice for communication satellites.
>
> By changing the altitude of a satellite in circular orbit, it is possible to change the speed of a satellite. The higher a satellite is, the slower its rotation. This makes it possible to calculate the exact height needed to place a satellite so that its speed gives it a rotation period of 24 hours, the same as earth's. This is known as a geostationary orbit. The plane of the satellite's orbit must contain the equator ("Satellite Communications," ***Encyclopedia of Electronics***). The height needed is 35,803 kilometers.

Mike's paper goes on to describe how the satellite receives and transmits signals, until it makes its way into your home television. The clarity with which Mike explains concepts like uplinks, transmitters, receivers, downlinks, signal bands, modulation, frequency deviations, and transponders turns a topic that might be mystifying into one that can be readily understood. The reader is left with little doubt that Mike understands this technology well. What is equally clear is that he is able to convey what he knows to others in clear, capable prose.

The change in the quality of student research papers over just two years of the Senior Project's development illustrates that the project has affected teaching -- and consequently, learning -- beyond the effects it has had on students' motivation and personal development. In the following section we examine how the faculty's work over these initial years created new learning opportunities for students.

Changes in Curriculum and Teaching

Hodgson teachers, having experienced first hand the salutary effects of the Senior

Project on students, are increasingly willing to consider changes in their curriculum and teaching practices in order to increase students' opportunities to succeed in the project. Godowsky explained how the staff has engaged in "backward planning" (McDonald, 1992, 1993) to determine needed changes: They observe and analyze the skills and knowledge students need to successfully meet the demands of the project and then design changes based on that information. Although initial resistance and conflict were common, most of the staff and students ultimately embraced the changes because they were persuaded by the results of the project -- including the hard work and motivation of the students -- and by the influence of a critical core of teachers vigorously encouraging their involvement. The project is a constant catalyst for whole-school inquiry on the issues of teaching and learning.

Reshaping Curriculum. One initial, direct change was the revision of the twelfth-grade English curriculum to include one semester of technical writing so that English teachers could teach students the skills necessary to write the research paper. In order to prepare lower-grade students for the research they will do as seniors, both academic and vocational teachers in grades nine through eleven have added research components to their courses and are increasingly developing project-based curricular units. Ninth-grade teaching teams introduce both research papers and oral presentations in both English and shop classes.

Two eleventh-grade teachers, Jim Lacey and Kay Bach, formed an interdisciplinary core team for the required American history and American literature courses, combining them into one course called *The American Experience*. One of the units in this course, which requires students to do a videotaped oral biography, is a direct outgrowth of the Senior Project's public presentation component and represents the school's efforts to provide students with the skills necessary for it.

In addition, *The American Experience* engages students in both individual and group projects, and in activities ranging from mock trials, simulations, and role-playing of important historical events and persons to oral histories, journals, and research papers. The course is organized around four major themes of American life -- the frontiers, war, diversity of people, and core values such as equality -- and around authentic questions that allow for many modes of exploration. The students develop many hands-on, experiential, as well as research-based, inroads into such questions as "How does diversity make America a stronger place?" "What values are constants in American life?" and "What qualities do Americans develop from crossing frontiers?"

The American Experience is one of several interdisciplinary courses that have been developed with the encouragement of block scheduling, an innovation implemented by Godowsky when requested by teacher teams with strong curricular ideas and a willingness to experiment. A biology/English block has just begun in the tenth grade, while ninth-grade English, science, and social studies are taught in a block schedule in which a group of teachers works with the same group of students. All of these provide opportunities for integrating disciplines, developing more authentic learning tasks, and coming to know students' minds and talents better.

Similarly, each mathematics teacher has been released from the usual course load for one period daily to work with a cluster of shops, teaching strands of theory in application. For example, the Pythagorean theorum and other aspects of geometry and algebra find a comfortable home in carpentry class. In the *Principles of Technology* course, technology and mathematics teachers teach scientific notation together. Over time, the integration of academic and vocational learning grows, as traditional academics are used to enable more powerful hands-on work, and vocational applications bring practical power and relevance to traditional academics.

Hodgson also has experimented with integrating other vocational and academic courses, such as horticulture and biology. Increasingly, academic and vocational teachers visit one another's classes to learn about one another's fields with an eye toward future collaboration. As ideas emerge, Godowsky remains committed to working through the scheduling changes required for block scheduling that allows interdisciplinary work.

These initiatives -- along with the move toward more authentic assessment -- also enhance the success of ongoing efforts to reduce tracking in the school. Hodgson has moved from a five-track curriculum that existed several years ago -- advanced placement, college preparatory, general, career, and special education -- to a curriculum that is increasingly nontracked, with heterogeneous classrooms and interdisciplinary/interprogrammatic courses of study replacing the old, highly programmed single-track models. Advanced placement courses no longer exist, and students with college and employment intentions take an increasing number of courses in common. Special education students participate in regular shop classes, and more are being mainstreamed into other regular classes as teachers with both special education and disciplinary backgrounds become part of teams in which they feel comfortable working with more special education students. The authentic assessment strategies often enable these students to experience greater success because they are allowed a wider range of options for demonstrating competence and understanding, and because performance tasks (in contrast to timed classroom tests, for example) can be structured to provide them with the time they need to complete a job well.

Redesigning Instruction. To the satisfaction of both staff and students, the Senior Project has helped to personalize instruction. It has demanded increased student-teacher interaction, casting teachers in the roles of mentor, coach, cheerleader, tutor, and mediator, as well as advisor. Anthony* commented that "The Senior Project involves teachers a lot more than when they would be teaching just regular stuff." Al Angel concurred: "The Senior Project has really brought us [students and teachers] closer. [The students] rebel all the way until they get almost through it; and then something clicks in their head and they say, 'This is kind of neat.'"

It is the power of relationships -- between students and staff and between staff and staff -- that helps to bring about change. The elixir of student success in the Senior Project propels the student-teacher relationship. Teachers are relentless in their determination that students will succeed. Students eventually acquiesce, applying more effort than they ever

thought they would or could exert to ensure their own success.

Staff relationships and increased collegiality sustain and strengthen the project as teachers encourage one another to persevere through student resistance and as they encourage one another to surmount their own resistance, to forsake old habits and practices for new ones, to open their doors and relax the age-old boundaries that traditionally have kept vocational and academic faculties isolated from one another. This building of community does not go unnoticed by the students. As special education student Frank reflected, "The Senior Project makes everybody come together a little bit more. It makes you feel like getting involved with the school a little bit more."

The school administration has changed the instructional schedule to accommodate the Senior Project, and individual teachers have used flexible scheduling for innovative instructional activities. In order to provide the necessary research and oral presentation skills to co-op students, who spend much of each day in on-the-job employment situations, a double period of English was added to their program. In their *American Experience* course, Lacey and his new partner, Carol Adams, regularly rearrange their classes and schedule based on their instructional goals.

Innovative practices include the English department's use of student-produced materials that provide concrete models of research papers for beginning researchers. The research papers of former students give current students an understanding of the criteria that will be used to grade their papers. Math teacher Robert Riehs has replaced what he calls his "chalk and talk" method of teaching with projects and math manipulatives. Faculty members note that the Senior Project has helped a lot of teachers look differently at the way they teach and at the way they measure what students do.

Because teachers experience the public presentation as a personal assessment of their teaching -- a form of public accountability -- it has prompted some to reflect on their teaching practices. Although teaching practice at Hodgson is still predominantly traditional, teachers are increasingly likely to direct students to find their own answers to questions, rather than to provide the answers themselves. They are increasingly likely to ask probing questions and create inquiry-oriented classroom activities, rather than simply to lecture. Teacher collaboration has increased. On some of the core teams, teachers give students a joint grade for their courses. They plan together, and they review students' work together.

As discussed earlier, the learning tasks that characterize the Senior Project have begun to find their way into classrooms before senior year, increasing students' opportunities throughout their high school years to engage in public presentations, active learning, interdisciplinary studies, and the integration of academic and vocational curricula. In the eleventh-grade *American Experience* course, for example, students formulate research questions and subsets of questions that will shape their research, often connecting these to their vocational studies. For example, students majoring in culinary arts did a project on ethnic foods.

Bach and Lacey believe that the juniors who go through this course will be much better prepared for the Senior Project. Confronted with a change from the passive modes of teaching and learning they have grown used to, the students often ask initially, "Can't we just learn out of the book?" By the end of the course, these students have had experience speaking before a group, doing research, and taking responsibility for a lot of their own learning. Bach observed that, although the students had to produce much more work for each grade they attained in this class, they also experienced lower rates of failure. The opportunity to take responsibility and to help fashion their own learning experiences stimulated greater effort and a sense of efficacy on the part of students.

In Riehs' math class, students spend increasing amounts of time developing problem solving strategies and engaging in inductive reasoning to formulate mathematical theories. In carpentry shop, students are also asked to do research, to write their own tests, and to develop their own vocabulary lists from their work. Lutz noted that students who have had the ninth-grade core-team experience have a different initial response to this kind of work than students who have been accustomed to asking the teacher to "Tell us the answer." Rather than responding with fear and claiming they can't do the work, these students seem to know how to get started, how to tackle a task, and how to ask questions that will give them the information they need to make progress. They seem more verbal, more involved, and more willing to work with one another. They also respond differently to lectures, Lutz felt, being more apt to ask thought-provoking questions about how things work and why, probing for theory and for depth rather than simply writing down information. In short, they are again becoming the inquiring learners they were when they entered kindergarten years ago, before they learned how to behave in school.

Creating New Opportunities for Students

The most dramatic changes brought about by the Senior Project have been in the kinds of learning activities students have the opportunity to engage in. The research paper, the product, and the presentation are characterized by authentic learning: Students research something they do not know in order to increase their knowledge -- not to obtain preconceived "correct" answers. Their research takes them into the world of work where they encounter what they are studying in practice. Neither the experiences nor the outcomes of the research strategy have been preplanned. Instead, students design their own research plan so that the projects develop organically, with individual needs and interests dictating the course of learning and with space for the intervention of serendipity.

The organic development of projects is illustrated by Frank's research activities on wells and Terrance's* activities for his sports journalism project, entitled "Using Information Systems and Service Skills in Sports Journalism." Terrance, an autistic student whose passion for sports statistics became the basis for his project, initiated and established contacts with local sports journalists, interviewed them, attended sports events with them, visited their offices, and interviewed coaches and student athletes at a local university. Terrance's networking landed him a summer job in the computer department of the University of

Delaware.

Senior Project tasks require active learning. Although students do more writing, technical reading, and library work, these activities are a means to an end, and the end is of their own design. As Frank explained, students are no longer simply "opening a book and writing questions and answering them." His experience in researching wells demonstrates the diverse range of activities in which students engage. Frank pointed out how authentic and active learning affected his attitude toward school: He said that the project "makes school cool. It's fun to be researching and working with other people. You're drafting the research paper, you're drawing up the blueprints on the well and putting it to scale, you're setting dates to interview people and meet with your teachers." Frank's recounting of the pattern of his activity illustrates the natural integration of academic and vocational experiences.

Other students also respond favorably to the variety of activities. Erica commented on the appeal of the sheer physicality of the activities, the fact that students can move around and go places to find out what they need to know, highlighting by contrast the boredom that accompanies passive desk-bound learning. Because students must do research beyond the secondary sources found in the school library, because they are required to locate and incorporate primary sources, the project's academic research component promotes its vocational component, along with active learning. Invariably, students visit job sites and interact with adult workers and local institutions: contractors, union officials, business and industry officials and workers, craftspersons, artisans, museums, hospitals, and research and development labs. Nearly every student research paper bibliography includes one or more interviews with workers or other experts in the field being studied. These interactions provide students with opportunities to become independent and mature: They develop confidence and communication skills.

Frank explained how students develop an understanding of the significance of communication skills: "When you go out to get jobs, it's a lot better if you can talk to people openly. You know, if you go out and start talking to somebody and you're nervous, they might think you're not qualified or businesslike." For Frank, the Senior Project experience has sharpened his understanding of the expectations, values, and conventions of the workplace and increased the skills he needs to achieve them.

Because students must forge their own way, the project places them at the center of their own learning where they, not the adults in their lives, orchestrate the movement of the experiences and resources necessary to complete the project. Autonomy, resourcefulness, and confidence in showing initiative are the results. Anthony said, "You learn how to get hold of people, to get people who know stuff to help you. You use people that might know something about what you need to know or know where you could find whatever you're looking for." Frank concurred, "You learn how to pick people who are qualified to answer your questions."

Despite their legendary resistance, the students become increasingly responsible as the

project thrusts the responsibility for their learning onto *them*. As Anthony explained: "The student has to do the whole thing themselves. We just have to grow up quicker and act more like mature adults." Al Angel pointed out that students' grades always go up, and the biggest leap occurs for the most marginal students.

Interestingly, some of the greatest success stories for the Senior Project are Hodgson's special education students. Special education teacher Carolyn Steinwedel reports that out of a total school population of 800, about 100 are identified for special education, mostly as learning disabled. These students -- many of whom have been with Steinwedel for four years -- work only on the Senior Project in their senior year, which leaves them more time in which to undertake this major piece of work. They do the same paper, presentation, and product as all the other students and are similarly evaluated by a committee of teachers, but their projects are structured with more checkpoints at which adults touch base to see that the work is progressing.

Steinwedel reported that, while her students initially showed more resistance to the project because they had more anxiety about change, they ultimately achieved both higher grades and much more profound learning than under the traditional system. The positive results for these students included increased self-esteem, sharpened skills, and a greater ability to find, and succeed at, jobs after high school. Steinwedel noted that the Senior Project "lets you teach to their strengths, engage their interest level more, and help kids develop their strengths and expertise so that they find a field they can pursue." The benefits to her students translate into benefits for Steinwedel as well: "I've taught school for 17 years," she remarked, "and [the Senior Project] is probably the most rewarding thing I've ever done."

The Senior Project's effects on students' school performance have included: higher rates of homework completion, higher grades, increased competence in writing and research ability, improvement in academic and vocational skills, and increased task commitment. These results are corroborated by the Student Survey.

The project has also affected the factors that improve student performance: motivation, attendance, initiative, self-confidence, effort, engagement, and perseverance. Students report that their knowledge has increased, their sense of being knowledgeable has increased, and that they have improved their time management capacity and organizational skills. Teachers report that their students have developed analytical skills and are better able to follow through with long-term goals and develop practical applications from technical information.

The Senior Project has even penetrated the student culture. Lunchtime conversations now include talk about the projects: When one student asked another about his weekend plans, the answer was, "I'm going to be working on my Senior Project." At the conclusion of the project, the vast majority of students report that they would prefer assessments such as the Senior Project to the traditional paper-and-pencil, multiple-choice tests even though the Senior Project is more difficult, more demanding, and more time consuming. The rewards for such

authentic assessments are greater; they bring more personal satisfaction and an increased sense of accomplishment.

Given the differences in the nature of the abilities being assessed, it would be unreasonable to expect the Senior Project to significantly influence Hodgson's standardized test scores. It is possible, however, that the companion efforts to integrate mathematics into the vocational curriculum had some bearing on the increase in the school's Stanford Achievement Test scores in math between 1991 and 1992. Other indicators of the success of the range of curriculum, teaching, and assessment changes at Hodgson may be gleaned from the fact that between 1990 and 1992, student attendance increased, infractions of school rules declined, and honor roll participation increased by almost 50 percent.

The importance of any direct effect of the Senior Project on such a disparate measure as standardized test scores is outweighed, however, by the fact that it has challenged the narrowness of traditional assessments by highlighting the contrasts in what is measured and in what they mean. In the presentation of his 3/4-inch scale residential house, with frame, rafters, joists, jambs, and beams complete and in place, Malik was able to recount, step-by-step, how he used the Pythagorean theorum to determine the pitch of the roof. On his SATs, however, he has been unable to achieve a cumulative score of 700, with the result that he will be denied an athletic scholarship for college.

With the increased use of authentic assessment, teachers have growing certainty that what they can see students actually doing is a stronger measure of their capabilities and potentials than are their scores on more abstract, multiple-choice tests. Consequently, they are more willing to challenge traditional assessments of students' abilities and to push them to greater achievements. And students themselves are beginning to believe that they can, and will, accomplish complex tasks; the kind of tasks they once thought were out of their league, based on their test scores. It is possible that at some point, the constraints on teaching and learning occasioned by the influence of less authentic assessments will be re-evaluated as the value of performance assessment is recognized by teachers, students, and their parents. As described in the following section, this is already beginning to happen in Delaware.

Challenges and Possibilities

In all schools engaged in change, new initiatives pose new problems and new possibilities. Issues that have emerged as the Senior Project was implemented are typical of those encountered in other schools attempting change:

- *initial student and teacher resistance to proposed changes*;

- *need for technical knowledge to support reform*, for example, development of new instructional strategies for courses integrating academic and vocational curriculum;

• *conflicts between traditional school regularities and the reform's new requirements* -- e.g., as finding time for students to work on their Senior Project research without stealing time from regularly scheduled classes, dealing with the logistics of managing projects for increasing numbers of seniors, or reinventing the schedule to allow for more interdisciplinary courses;

• *conflicts with district and state curriculum and assessment mandates* -- e.g., the district senior English curriculum on British literature versus Hodgson's technical writing course or new state certification exams in vocational areas that require traditional course configurations, undermining Hodgson's more integrated approach; and

• *institutionalization of the reform* -- creating strategies for building teacher and school capacity to achieve the goal of diploma-by-exhibition.

Any substantive change attempted in a complex organization will inevitably bring about other changes that the institution may or may not have the will and capacity to respond to. In some respects, Hodgson has had a unique advantage in confronting these challenges. Because it was recently "recreated" as a merged academic and vocational-technical school, it possesses some of the characteristics of a new school, one in which new norms and ways of working could be fashioned in the breach of discontinuities created by a mandated, district-level initiative. As Godowsky put it, "We're young as an academic school. We're building our future here. . . . The old approach [of having vocational courses only] is dying out. If we don't bring reading, writing, and thinking into vocational programs, we're missing the boat." At the same time, Hodgson has had the advantage of having been a vocational school in which the concepts of "student as worker" and performance-based assessment were natural rather than alien ideas. As Dave Lutz observed, "Our kids demonstrate their knowledge every day in vocational work."

A new mix of staff, some early retirements, and a changed mission allowed new thinking to begin to find a foothold. Careful, respectful change processes allowed it to expand. From the very beginning, when staff conversations first took place before school hours and over dinners, a priority was always placed on inclusiveness of interested staff and widespread sharing of information. When the Senior Project Committee was formed, copies of all committee meeting minutes were sent to all school staff. The committee members used their personal relationships as a basis for reaching out, and all ideas and documents were developed by faculty members working together in committees and teams, rather than "brought in" by outside experts -- although a number of outsiders with ideas that proved useful were part of the process at various points. Echoing the constructivist reality of all change efforts, one Hodgson teacher observed that "The best things we've done are those we've done ourselves . . . for example, working through our mission statement."

Another helpful factor has been the leadership of the district superintendent, Dr. Dennis Loftus, who supports change and is willing to seriously consider new ideas.

Godowsky, who describes Loftus as an innovator and a mentor, noted wryly that "Another good thing is that we fight the district on issues of importance, and sometimes we even win." The school has proposed curriculum and scheduling revisions to the district that have met with approval, thereby enabling the institution of more interdisciplinary initiatives and time for team planning for teachers. The conflict between the school's senior writing course and the district's British literature curriculum, for example, was ultimately resolved in favor of the school's program, allowing the continued integration of curriculum necessary for the interdisciplinary Senior Project. With school-site control over staffing and budgeting, Godowsky also has been able to begin to reduce teachers' course loads by rethinking programs and staffing, eliminating some pullout remedial classes and staff in order to invest in the core program.

Finally, beginning in 1993, support for authentic assessment began to be forthcoming from the state. Delaware took the decisive step of dropping its norm-referenced, multiple-choice, standardized testing program at the state level and introducing instead a performance-based test in reading, writing, and mathematics that is an interim step enroute to a more full-blown system of portfolios and performance assessments. This step may lend greater support to schools attempting to move "beyond the bubble" in their own assessment efforts, and may legitimize and strengthen the commitments of time, energy, and inventiveness that faculty, students, and parents are willing and able to expend.

The fact remains, however, that major change is never easy. Time constraints have always been, and continue to be, problematic. Initially, teachers volunteered all the time necessary to begin the Senior Project initiative: time for conversations, individual meetings with students, committee participation, and coverage to release teachers for participation at public presentations. Because teachers were not being compensated for the extra time they were devoting to the project, Godowsky requested from the district, and was granted, permission to change the class and bus schedule in order to provide teachers with one daily period for professional development activities. This was accomplished without any reduction in instructional time. Despite this, a number of other issues remain to be resolved: class time required for teachers to participate in public presentations disrupts the instructional continuity of classes, and students sometimes complain that they miss their teachers.

The Senior Project has expanded the narrow and conventional conception of teaching work defined as that which occurs with one teacher in a classroom with a full class. Teaching work for the Senior Project is more collaborative and calls for more diverse teacher roles. In fact, if teachers had not been willing to diversify their roles and their work, the Senior Project would never have made it past the drawing board. Teachers participating in the Senior Project work on governance and design committees. At formal and informal meetings, they collaborate to inform, encourage, and persuade their colleagues to join the project. In many one-on-one interactions with students, they advise, facilitate, encourage, tutor, and mentor, as well as periodically critiquing research papers of students who may or may not be in their own classes. They participate in evaluations with the project committees of various students they are advising. The new kinds of learning that result from the Senior

Project, therefore, can occur only if teachers adopt new and diverse roles that fundamentally reconceptualize their work. Learning cannot change if teaching work doesn't change.

The new notions of teaching work at Hodgson also include inventing and managing the school's change process. Hodgson could have adopted any of the fashionable models for site-based management or shared decision making or invited any number of "experts" to design and plan a new assessment. Instead, they chose to engage in a process of inquiry and to invent their own grassroots process for community building and change. This process is characterized by an ethos of inclusion, and depends on interpersonal relations, frequent, regularized communication, and whole-school inquiry and reflection.

To cite just one example of the fruits of the many committee activities occurring under staff leadership, faculty recently planned an inservice day in which they developed and ran their own series of workshops centered around some of the core issues at the school: integrating mathematics into other curriculum areas; creating vocational subject clusters; core-team planning; inclusion of special education students in courses; schoolwide reward and incentive plans; and a survey of all students, parents, and teachers.

Perhaps even more interesting, and certainly more unusual, was a two-period inservice experience for both students and teachers in which they jointly discussed the school's mission statement and two of the Coalition of Essential School's key principles: establishing a "tone of decency," and viewing the "student as worker." Together, students and teachers discussed what they felt these ideas should mean and how well they thought the school was pursuing these goals. In these and in other events, the school community simultaneously creates, achieves, and revises its collective work, which evolves as the staff and students grow and change together.

Increasingly, Hodgson is able to see itself as a dynamic educational community continuously creating itself according to its own assessment of goals and needs. As the staff's confidence in themselves as agents of their own change increases, they become more able to forsake their dependence on time-worn rituals that have outlived their effectiveness. This is demonstrated by increasing support for the project. As increasing numbers of teachers observe first hand the project's effects on students, their resistance diminishes, and they become more receptive, not only to the project itself, but to its underlying educational principles. This conversion is necessary if the reform is to last and if its implications for teaching and learning are to be fully realized. Hodgson's grassroots change process has enabled the school to put the needs of its students at the center of its reform efforts.

Conclusions

Hodgson's Senior Project supports a growing number of authentic teaching and learning opportunities throughout the school both before and during senior year. It also encourages integrated vocational and academic learning. The assessment adds an intellectual

component to the traditional competency and performance-based vocational assessment. It evaluates students' intellectual knowledge of their vocational specialty, along with the traditionally academic skills of research, writing, and communication. Criteria for the public presentation are drawn from the traditions of both academic and vocational education: The use of research conventions and a press for higher-order thinking skills are normally thought to be the domain of the academic tradition, while the use of demonstrations and products to assess competency emerges out of what is normally considered the vocational tradition.

The assessment creates an interdependency between learning that is "hands-on" and "minds-on." This interdependency connects the academic and vocational domains, but it also extends students' knowledge and skills in both of the domains, as each plays off the other. The Senior Project diminishes the traditional division between those who work with their hands and those who work with their heads, along with the pernicious class and status distinctions associated with this view. As Scarbrough commented, "If they're going to be plumbers, carpenters, masons, cosmetologists, why can't they also be educated plumbers, educated carpenters, educated masons, educated cosmetologists? Why do they have to choose between labor and intellect? Why can't they have both?" The assessment provokes teachers to think more deeply about the possibilities of academic and vocational integration in their shop and academic subject curricula, as exemplified in the way in which Al Angel considered how he would like to integrate both math and physics into his dental lab.

The new assessments, even in their early stages, have impressive potential for bringing into closer correspondence the tasks and values of school and the workplace. The tasks of the Senior Project are authentic, as are workplace tasks. Students are held accountable for their work, and assume responsibility for their project, as they would in the workplace. Workplace values such as cooperation, initiative, and standards of quality are emphasized both in the process of the assessment and in the evaluation component. According to Scarbrough:

> The project enhances students' capacities to do their job, because they're better communicators on the job. They can read, write, speak, and listen better as auto technicians than they did before. Students are learning life skills: problem solving, how to be a good worker, how to give and follow directions, how to pose and find answers to questions.

The project teaches students to challenge themselves. It gives them experience coping with the pressure of deadlines and with resistance, frustration, and the anxiety of risk taking inherent to self-challenging work. It rewards those who challenge themselves most.

Perhaps the most powerful lesson is that work should be meaningful rather than perfunctory; that work should bring pleasure rather than boredom. And it teaches both students and teachers to be conscious of these distinctions in school and in the workplace. Unfortunately, the traditional lessons of school and, for many, of the workplace, are the reverse. Hodgson's Senior Project endows school work with a dignity that it is often deprived of, especially for students who are not engaged in college preparatory work. It

teaches, as Al Angel said, that vocational work is about "using your hands and your mind well together." It enables students to develop a sense of professionalism about their fields as they acquire a level of specialized knowledge and expertise. It raises not only their competence but their expectations as well, thus opening new doors to a future full of promise for these young people who feel capable of reaching for it.

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Appendix

Sample Student Research Paper

SATELLITE COMMUNICATION SYSTEMS

English 12
March 8, 1993

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SATELLITE COMMUNICATION SYSTEMS

" 'This is a great day with me and I feel I have at last struck the solution of a great problem -- and the day is coming when telephone wires will be laid into houses, just like water or gas. and friends converse with each other without leaving home." So wrote Alexander Graham Bell on the 10th March 1876, the day when he first successfully demonstrated his telephone." (Dalgleish 1) Although Bell showed extreme foresight with his prediction, even he would be in awe of our many achievements in communication. By using satellites, we have been able to shrink the world in which we live, allowing us to be on top of events as they happen. The world sat on the edge as it watched live footage of the bombing of Bagdad. We were there as U.S. troops landed on the shore of Somalia. Real-time reporting makes it possible for us to instantly be a part of what happens around us.

History

The world's first active communications satellite, SCORE, was launched by NASA (National Aeronautics and Space Administration) in 1958. SCORE weighed 150 kilograms, with an orbit ranging from 180 to 1490 kilometers, and functioned for twelve days on battery power. The satellite transmitted a prerecorded message from President Eisenhower to the nation.

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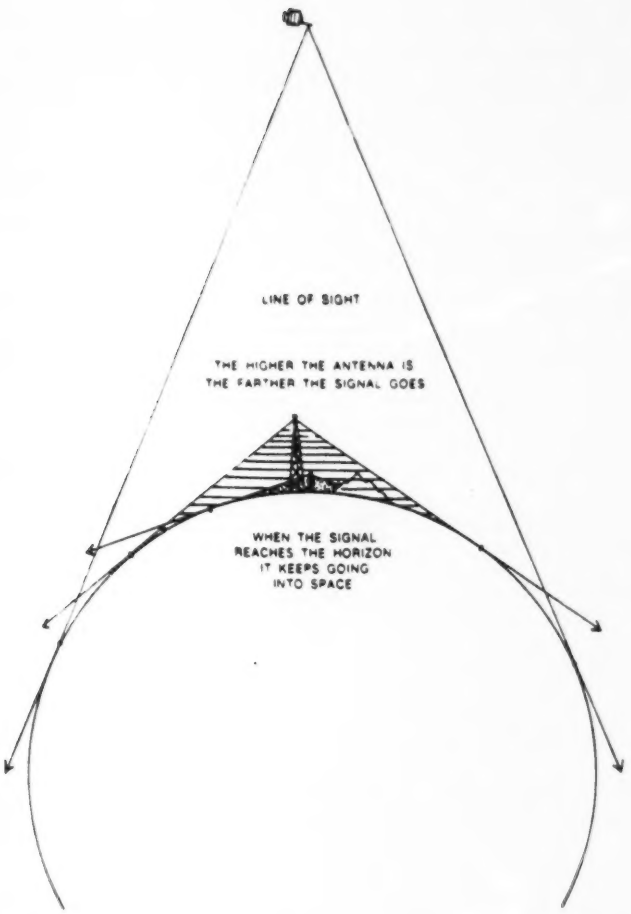

Figure 1 - Picture of Radio Waves (Bendick 34)

Satellites transmit messages and other information by using radio signals. These radio signals are actually electromagnetic waves that, when modulated or systematically changed, can carry information. Because of the curvature of the earth and due to the fact that radio waves travel in straight lines (see Figure 1), two options were available for transmitting over long distances. The first option was to build an extensive network of radio-relay stations; however, this

proved to be expensive and highly impractical. The second was to reflect the radio signals from a high-enough altitude that they would be receivable at points otherwise unreachable due to the earth's curve. It was believed that, by putting large metal-coated balloons in orbit, the second option would, in fact, be feasible. In the early sixties, a number of experiments, beginning with ECHO I, were conducted to accomplish this. However, these experiments proved that reflecting a signal was impractical because too much power was required to return a useable signal.

COURIER, launched by the U.S. Defense Department in 1960, was the world's first fully-active repeater satellite. That is, it received and successfully transmitted back speech and telegraphy. It, too, had a short life and lasted only seventeen days. For the first time, solar-powered cells were used as the energy source.

In 1962 TELSTAR I was launched by AT&T. This satellite was the first to carry on-board antenna and amplification equipment. It was the first one to transmit and receive simultaneously. It was also the first satellite to use the combination of solar cells and rechargeable batteries as energy source.

Up to this point the satellites had been placed at relatively low altitudes and in eliptical orbits, because we did

not possess the ability to launch a rocket higher than 10,000 kilometers above the earth. In 1964, however, the U.S. was able to place a satellite, SYNCOM 3, into a geostationary orbit. This allowed an earth station to stay in constant line-of-sight contact with the satellite. The first continuous live trans-pacific television broadcast, the 1964 Olympic Games from Japan, was made possible using the SYNCOM satellite.

Organizations

The International Telecommunications Satellite Organizaiton (Intelsat) was established in 1964 to provide the world's first global satellite communications system. It began operating in 1965, using EARLY BIRD (INTELSAT I), to broadcast the first satellite-relayed telephone and television services between Europe and North America. Intelsat is one of the world's most successful international business cooperatives, counting over 109 countries as members.

As agency of the U.S. government, the National Aeronautics and Space Administration (NASA) is widely involved in space exploration and research. In Japan the National Space Development Agency is NASA's counterpart. In Europe the European Space Agency (ESA) is similarly involved in space research, but also operates communication and broadcast satellites. A system that serves the U.S. Navy and merchant

marine is Marisat. The International Maritime Satellite Organization (Inmarsat) was organized in 1979. It is generally patterned after Intelsat and provides communications for ships and offshore oil platforms.

Satellite Positioning in Space

The path a satellite follows around the earth is known as its orbit. There are two types of orbits: elliptical and circular. An elliptical orbit such as the one shown in Figure 2 is simply an elongated circle. This means it has an apogee and a perigee. The apogee is the point during the orbit where the satellite is at its slowest speed and is at its farthest distance from the earth. The perigee, on the other hand, is the point during the orbit where the satellite is at its closest distance to the earth and at its fastest speed. (Bleazard 25)

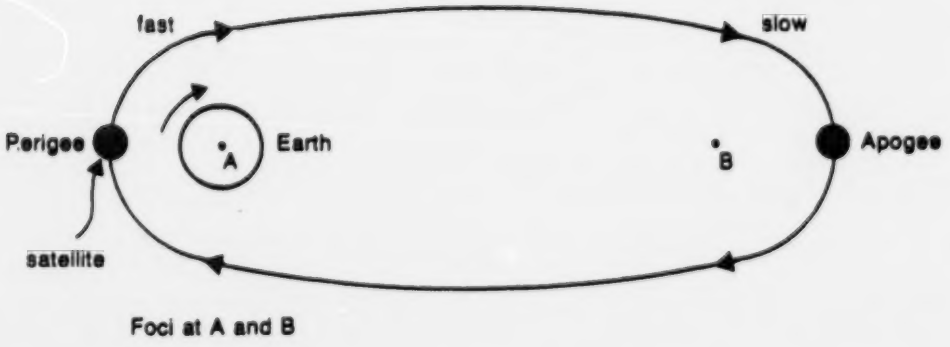

Figure 2 - Diagram of an Elliptical Orbit (Bleazard 69)

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A circular orbit is just that, a circle. Throughout the satellite's path, it remains at the same speed and distance from the earth.

Due to the fact that a satellite must be in direct sight in order to send or receive to or from a given point on earth, it is important to know the amount of time a satellite is in view. The longer the satellite is in view, the more data that is able to be sent and received. A satellite in an elliptical orbit will be in sight for varying amounts of time during its orbit. This makes it hard to predict and follow. Satellites in circular orbits, however, are visible for the same amount of time every time they appear. Because they are predictable, they are much easier to follow. This made circular orbits the best choice for communication satellites.

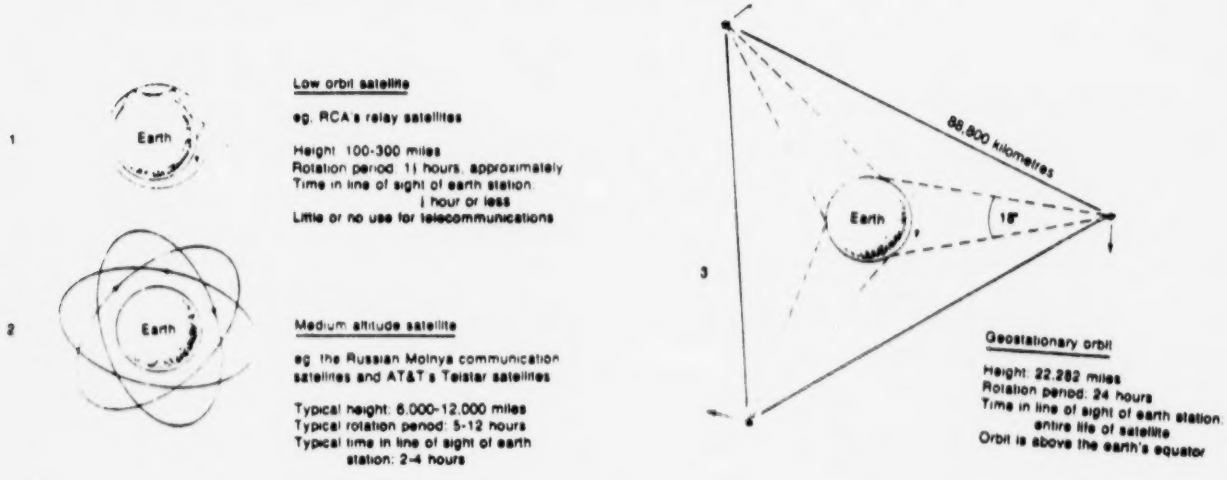

Figure 3 - Diagram of Circular Satellite Orbits (Bleazard 78)

By changing the altitude of a satellite in circular orbit, it is possible to change the speed of a satellite. The higher a satellite is, the slower its rotation. This makes it possible to calculate the exact height needed to place a satellite so that its speed gives it a rotation period of 24 hours, the same as earth's. (See Figure 3.) This is known as a geostationary orbit. The plane of the satellite's orbit must contain the equator ("Satellite Communications, Encyclopedia of Electronics). The height needed is 35,803 kilometers. To put this into perspective, trying to actually see a satellite from earth is equivalent to trying to see a dime from about 100 miles away. The geostationary orbit is important because it allows an earth station to stay in constant contact with the satellite. (Stephenson 10)

The orbit encircling the earth 35,803 kilometers out is known as the Clarke belt (see Figure 4). The belt is named after science-fiction writer Arthur C. Clarke. Clarke is often considered the man who originated the idea of geostationary satellites with this statement: "An 'artificial satellite' at the correct distance from the Earth would make one revolution every 24 hours; ie it would remain stationary above the same spot and would be within optical range of nearly half the Earth's surface. Three repeater stations, 120 degrees apart in the correct orbit, could give television and microwave coverage to the entire planet." (Bleazard 23)

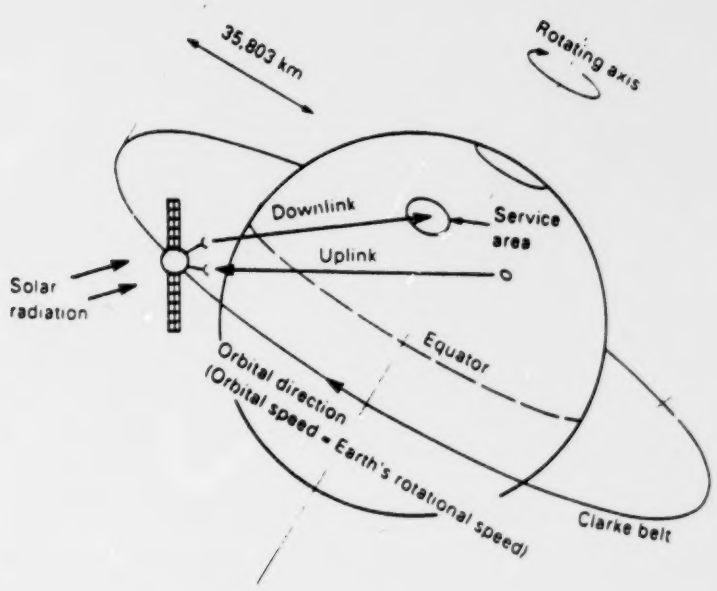

Figure 4 - Diagram of the Clarke Belt (Stephenson 18)

In order to insure that there is no interference between satellites, they are organized into slots. There are a total of 90 slots. Each satellite is about 1,832 miles or four degrees away from its nearest neighbor in the orbit. (Bleazard 74)

Sending and Receiving Signals

There are three major components to a satellite system. The first component is an uplink ground station. The ground station is primarily a transmitter. It takes a signal, usually a television signal, and sends it to the satellite.

The second component is the orbiting satellite itself. This device consists of two major subsystems, a transmitter and a receiver. When the two subsystems work in unison, they act as

a signal relay. The signal is received by the satellite and then retransmitted back to earth at a different angle.

Finally, there is the receiver, otherwise known as an earth station. The earth station is responsible for retrieving the signal from the satellite. Once the signal has been received, it is then converted back to a usable form. (See Figure 5.)

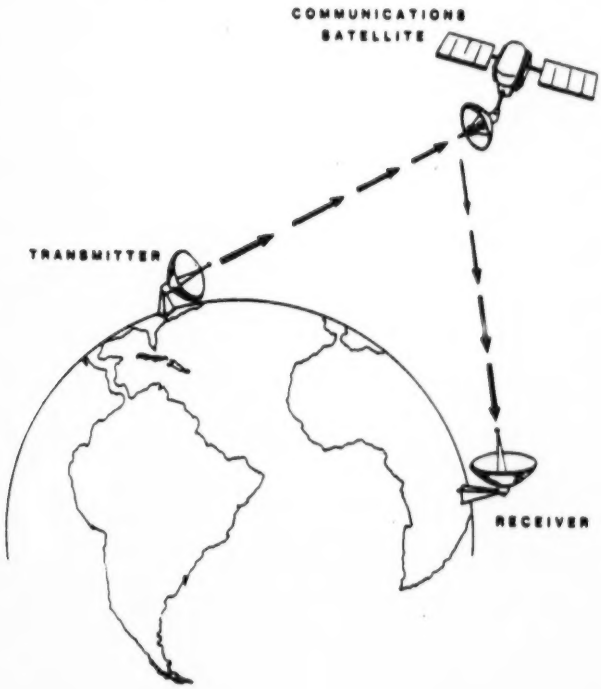

Figure 5 - Diagram of Complete Satellite System (White 58)

In commercially used satellites, there are two signal bands used. The first band is known as the C band. It operates between four and six gigahertz (GHz). The second is the Ku band. It operates between 12 and 14 GHz. (Cook 198) Both

bands are used, but for different purposes. C band is most commonly used for TV communication services, due to the fact that it has lower operating costs and it is subject to less degradation by harsh weather. Ku band is used almost universally for satellite news gathering (SNG) service because it requires smaller antennas and does not interfere with microwave transmission. (Inglis 38)

Once the material to be viewed has been selected -- whether "Gilligan's Island" reruns or the President's address -- it must have a way to reach the satellite. The method of sending it to the satellite is known as uplinking. A specific radio frequency from either the C or the Ku band is designated as the uplink carrier. That is, it will be used as a medium to transport information from earth to the satellite. Along with the audio and video signals, a series of control commands is also sent to the satellite via the uplink carrier. These control commands keep the satellite in proper alignment with respect to the earth station. There are now four components involved in delivering a signal to the satellite. The process of loading the audio, video and control signals onto the carrier signal is known as modulation.

The primary form of modulation used for satellite transmissions is frequency modulation (FM). A base frequency is selected for the carrier wave. By changing the base frequency

up or down, information is encoded onto the carrier. The total positive and negative deviation from the base frequency is known as frequency deviation. (Gerrish and Dugger 313) Each uplink carrier is allowed frequency deviation of 20 MHz (Clifford 47).

Now that the signal is at the satellite it must be processed and sent back to earth. The first step is to filter the signal. The filtering process demodulates the control signal, sending it to the appropriate component within the satellite itself, while removing unwanted noise. The next step is to down-convert the signal to a lower frequency. This is done so that the uplink signal does not interfere or "cross-talk" with the downlink signal. For example, if a signal were being transmitted on the C band, the uplink carrier would be at 5.8 GHz and the downlink carrier would be at 4.8 GHz. (Cook 198) Finally, the signal is boosted by a high-powered amplifier and returned back to earth. This process of down-converting, amplifying, and returning the signal is known as the downlinking.

A transponder is the device on the satellite that is used to receive a signal, convert it, and then re-transmit it back to earth (Clifford 246). The transponder is capable of handling only one carrier signal at a time; thus, every signal, or channel, must have its own transponder. A satellite with more than one transponder, then, will have more than one channel. Most communication satellites now in use are equipped with 24

transponders. This gives them the ability to handle 24 channels. (Clifford 25)

Once the signal has been re-transmitted back to earth, it is picked up by a satellite receiving antenna. The more powerful the satellite -- and the stronger its signals --, the smaller the antenna required (O'Malley 96). Although the antenna can be almost any shape, it is most commonly a parabolic dish. Since the antenna or 'dish' is concerned with the collection of extremely weak microwave signals and bringing them to a focus, its surface must be highly reflective to microwaves. The three-dimensional geometric shape called a paraboloid "has the unique property of bringing all incident radiation, parallel to its axis, to a focus" (Stephenson 13). In

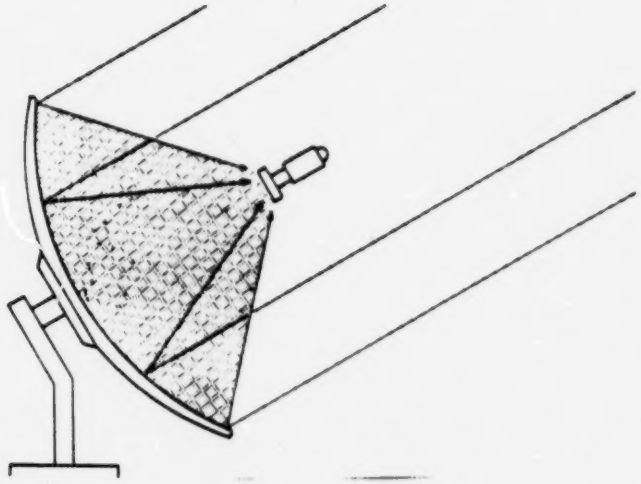

Figure 6 - Diagram of Parabolic Dish (Long and Keating 56)

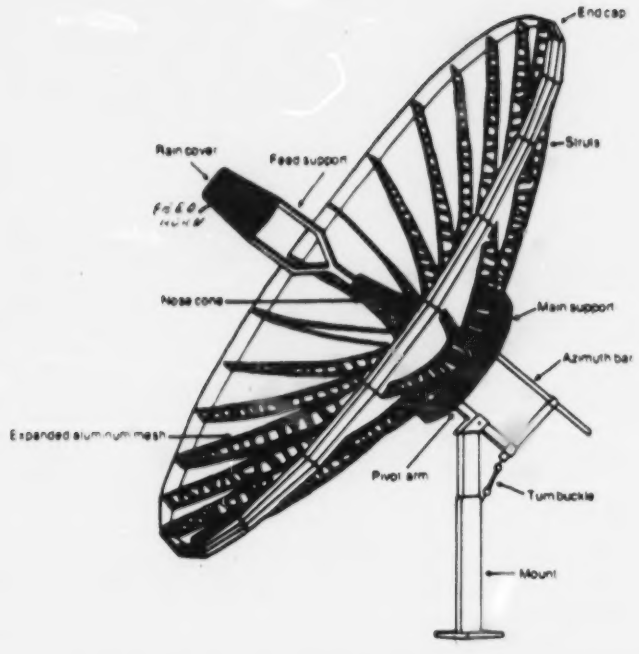

Figure 7 - Diagram of Dish Antenna (Clifford 78)

other words, any signal that enters the circumference of the dish will be reflected to a focal point above the dish. (See Figure 6.) This focal point is where the feedhorn is located (See Figure 7). The feedhorn is a device which collects the reflected signals and sends them, via cable, to the receiving unit. The receiver then projects the signal onto a TV screen.

After doing the research for this paper, I am certain that we are just now beginning to understand the full potential of satellite communications. Looking ahead to the possibilities that await, I feel that Arthur C. Clarke put it best:

> "For the one fact about the future of which we can be certain is that it will be utterly fantastic." (Global Trash)

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